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World Economic and Social Survey 2011: The Great Green Technological Transformation

Overview

Summary

In the next three to four decades, humankind must manage a fundamental technological overhaul or risk failure in fulfilling global commitments to end poverty and averting the catastrophic impacts of climate change and environmental degradation. The *World Economic and Social Survey 2011* analyses the options and challenges associated with the shift to more efficient and renewable energy technologies, with transforming agricultural technologies so as to guarantee food security without further degrading land and water resources, and with applying the technology required to adapt to climate change and reduce risks to human populations from natural hazards.

Governments will have to take a leading role through implementation of investment and incentive schemes designed to accelerate green technological innovation and structural change directed towards sustainable production and consumption. Strengthened international cooperation and significant adjustments in multilateral trade and financing mechanisms will be needed if developing countries are to effect the necessary technological transformation without compromising their aspirations regarding growth and poverty reduction.

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The green technological transformation

"Business as usual" is not an option

While humankind has made enormous progress in improving material welfare over the past two centuries, this progress has come at the lasting cost of degradation of our natural environment. About half of the forests that covered the earth are gone, groundwater resources are being depleted and contaminated, enormous reductions in biodiversity have already taken place and, through increased burning of fossil fuels, the stability of the planet's climate is being threatened by global warming. In order for populations in developing countries to achieve a decent living standard — especially the billions who currently still live in conditions of abject poverty, and the additional 2 billion people who will have been added to the world's population by mid-century — much greater economic progress will be needed.

Continuation along previously trodden economic growth pathways will further exacerbate the pressures exerted on the world's resources and natural environment, which would approach limits where livelihoods were no longer sustainable. Business as usual is thus not an option. Yet, even if we stop global engines of growth now, the depletion and pollution of our natural environment would still continue because of existing consumption patterns and production methods. Hence, there is an urgent need to find new development pathways which would ensure environmental sustainability and reverse ecological destruction, while managing to provide, now and in the future, a decent livelihood for all of humankind.

The green economy is to become the new paradigm

To achieve this goal, a radically new economic strategy will be needed. Economic decision-making, by Governments and private agents alike, will need to focus on ways to strengthen, rather than endanger, environmental sustainability. The "green economy" has been promoted as the key concept in this regard — the concept that embodies the promise of a new development paradigm, whose application has the potential to ensure the preservation of the Earth's ecosystem along new economic growth pathways while contributing at the same time to poverty reduction.

There is no unique definition of the green economy concept, but there is broad agreement on the basic idea underpinning it, namely, that enhancing economic growth, social progress and environmental stewardship can be complementary strategic objectives and that the need for possible trade-offs among them en route to their realization can be overcome. In this sense, the focus of the concept is fully consistent with that of the sustainable development concept elaborated by the United Nations, which perceives the economic, social and environmental dimensions as the three pillars of development and which stresses the importance of intergenerational equity in development, that is, ensuring that meeting the needs of the present generation does not compromise the ability of future generations to meet their own needs.

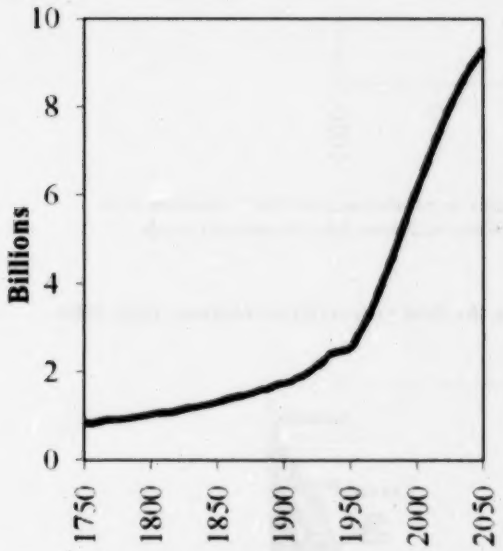
Further, the green economy concept is based on the conviction that the benefits of investing in environmental sustainability outweigh the cost of not doing so, as much as it outweighs the cost of having to protect ecosystems from the damages caused by a "non-green" (brown) economy.

A technological revolution is needed ...

Growth of the world population, per capita income, energy and resource use, waste and the production of pollutants (including greenhouse gas emissions) have all increased exponentially since the first industrial revolution. A depiction of these increases assumes the shape of a hockey stick (see figure O.1 (a) to (d)). The related increase in the level of human activity is threatening to surpass the limits of the Earth's capacity as a source and sink.

The objective of the green economy is to ensure that those limits are not crossed. One option for achieving this would be to limit income growth, as it would also, given existing production methods, limit the growth of resource use, waste and pollutants.

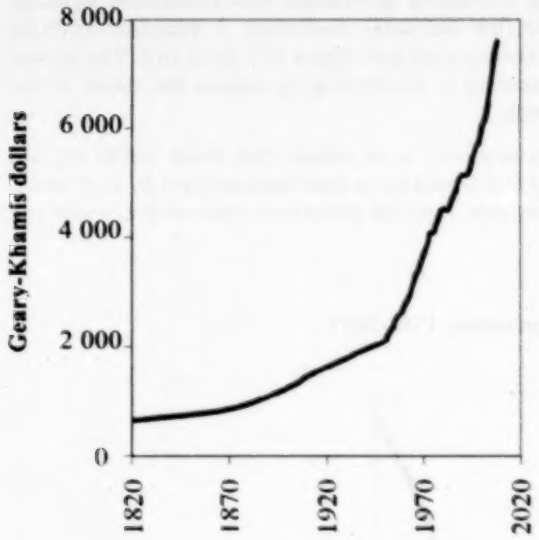
Figure O.1 (a)
Exponential growth of world population, 1750-2050



Sources: For 1750-1949, United Nations, "The world at six billion" (1999), p. 5, table 1, entitled "World population, year 0 to near stabilization"; for 1950-2050, United Nations, Department of Economic and Social Affairs, Population Division, "World Population Prospects: The 2010 Revision" (medium variant) (New York, 2011).

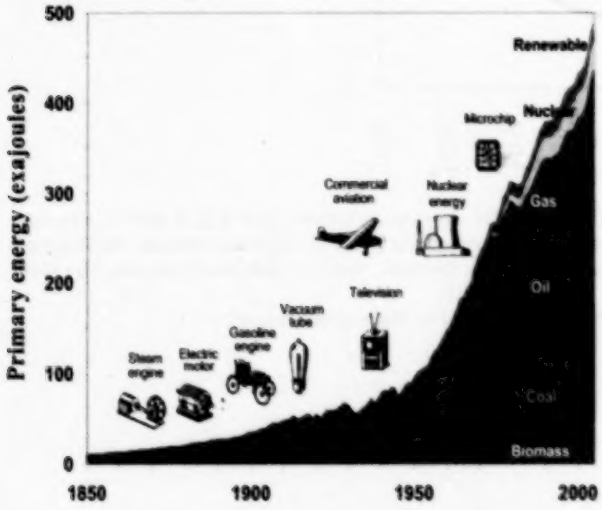
Note: Projections begin after 2010, and are based on the medium variant.

Figure O.1 (b)
Rapid growth of world per capita income, 1820-2008
(1990 international Geary-Khamis dollars)



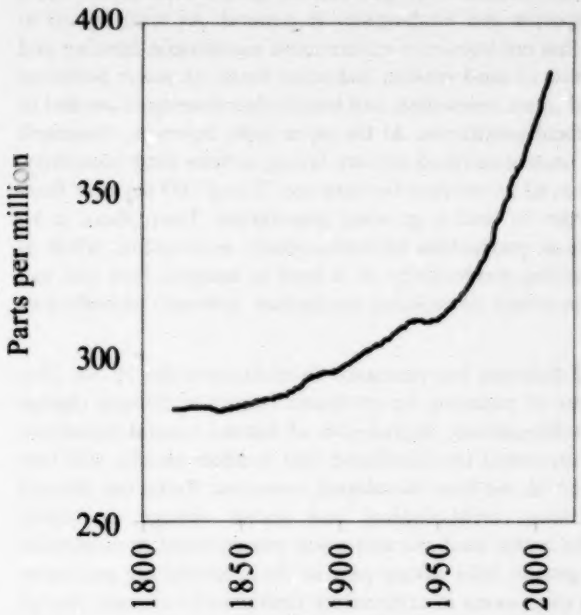
Source: Angus Maddison, "Maddison data on population and GDP". Available from http://sites.google.com/site/econgeodata/maddison-data-on-population-gdp.

Figure O.1 (c)
Rise in energy consumption since the first industrial revolution, 1850-2000
(Primary energy use in exajoules)



Source: *World Economic and Social Survey 2009* (United Nations publication, Sales No. E.09.II.C.1), figure II.4.

Figure O.1 (d)
Exponential increase in greenhouse gas emissions, 1816-2008
(Atmospheric carbon dioxide concentration: parts per million)



Source: Carbon Dioxide Information Analysis Center (CDIAC) (see http://cdiac.esd.ornl.gov).

However, doing so would complicate efforts to meet the development objective and would thus not be in the interest of developing countries, which are home to the vast majority of the world's population. Reducing population growth could be another option; but this could be achieved more effectively by improving living standards. Reducing non-renewable energy and resource use, reducing waste and pollutants, and reversing land degradation and biodiversity losses would then seem key to greening the economy.

A fundamental technological overhaul will be required. Technologies will need to undergo drastic changes so as to become more efficient in the use of energy and other resources and minimize the generation of harmful pollutants. At present, 90 per cent of energy is generated through brown technologies that utilize fossil fuels, with this type of production being responsible for about 60 per cent of carbon dioxide (CO_2) emissions. According to the more cautious scenario, for CO_2 equivalent concentrations to be stabilized at 450 parts per million (consistent with the target of stabilizing global warming at a 2° C temperature increase from pre-industrial levels), the use of fossil fuels would need to drop by 80 per cent by mid-century. Reducing the energy use and greenhouse gas emissions associated with growing and increasingly urban populations will require drastic changes in consumption patterns, transportation systems, residential and building infrastructure, and water and sanitation systems.

Modern agriculture, which underpins global food security, currently contributes about 14 per cent of greenhouse gas emissions, and the land-use and water management related thereto are not sustainable in many parts of the world. Deforestation is contributing an estimated 17 per cent of global emissions, while causing the loss of habitat, species and biodiversity in general. As with regard to energy, technologies do exist that are known to ensure more sustainable farming and forestry management, prevention of land erosion and strict limits on water pollution by agriculture, but a great deal more innovation and knowledge-sharing is needed to allow for their adaptation to local conditions. At the same time, however, inasmuch as nearly 1 billion people are undernourished and are facing serious food insecurity, global food production would need to increase by between 70 and 100 per cent from present levels by 2050 in order to feed a growing population. Thus, there is an urgent need to make agricultural production environmentally sustainable, while at the same time substantially raising productivity. It is hard to imagine how this can be attained without a major overhaul of existing production systems, technologies and supporting infrastructure.

The incidence of natural disasters has increased fivefold since the 1970s. This increase can, with a fair degree of certainty, be attributed in part to climate change induced by human activity. Deforestation, degradation of natural coastal protection and poor infrastructure have increased the likelihood that weather shocks will turn into human disasters, especially in the least developed countries. Reducing disaster risk will then entail significant technological and social change, including rebuilding of infrastructure and better land-use and water management in vulnerable areas with vulnerable social groups fully taking part in decision-making processes related to the implementation of systems of community resilience to climate change and disasters.

... which will be like no other

Many of the technologies needed for a green economy are already available, as evidenced, for example, by the range of options for generating renewable energy (wind, solar power and biofuels, among others), technologies for carbon capture and more efficient energy use, techniques to replace non-biodegradable resources, and sustainable farming and forestry techniques, as well as technologies to render coastlines and infrastructure less prone to natural disasters. These options offer readily usable starting points. The main challenges to jump-starting the shift to a green economy lie in how to further improve these techniques, adapt them to specific local and sectoral needs, scale up the applications so as to bring down significantly their costs, and provide incentives and mechanisms that will facilitate their diffusion and knowledge-sharing. Meeting these challenges successfully is easier said than done.

As so many of the components of existing economic systems are "locked into" the use of non-green and non-sustainable technologies, much is at stake in terms of the high cost of moving out of those technologies. Developing countries, especially low-income ones, with relatively low rates of electricity usage, may be able to "leapfrog" into electricity generation based on renewable forms of primary energy, for instance. The question is how to enable those countries to access, utilize and, above all, afford green technologies.

Further innovation and scaling up are also needed to drive down unit costs. Technologies will need to be "transferred" and made accessible, since most innovation takes place in the developed countries and private corporations in those countries are the main owners of the intellectual property rights covering most green technologies. The new technologies will also need to be locked into new production processes. This would imply improving much existing infrastructure and actively promoting green technologies and industries. Consequently, the technological revolution for a green economy will be fundamentally different from previous revolutions — in three ways.

First, it will have to take place within a specific and limited time period. Given existing pressures on our ecosystem, the goal would need to be achieved within the next three to four decades — a huge challenge, given that diffusion of technologies is a slow process. Previous technological revolutions typically required a substantially longer period of time than that available now to accomplish the required green technology revolution.

Second, Governments will have to assume a much more central role, the limited time frame being one key reason for this. Under current circumstances, there needs to be an acceleration of technological innovation and diffusion, which is unlikely to occur if they are left to market forces. Equally important is the fact that the natural environment is a public good and not "priced" by the market. Markets for green technologies do exist, but they are just developing, created through government policy. Governments will also have to play a key role in promoting further research on and development of green technologies and their diffusion, inasmuch as the benefits will accrue to whole societies. In addition, since at present existing brown technologies are locked into the entire economic system, a radical shift to green technologies will mean improving, adjusting and replacing much existing infrastructure and other invested capital. Such transformations will be costly and necessitate large-scale long-term financing, which is unlikely to be mobilized in full through private initiative and will require government support and incentives. Thus, not only will strong technology policies be needed, but they must go hand in hand with active industrial and educational policies aimed at inducing the necessary changes in infrastructure and in production processes.

Third, since the environmental challenges are global, the green technological revolution will need to be facilitated by intense international cooperation. While the global dimension is most obvious in the case of climate change, problems of food insecurity and deforestation have significant cross-border effects as well, stemming, for example, from food price instability and greenhouse gas emissions. Through international trade and investment, incomes and consumption in one country are linked to the ecological footprints left in the country of production. Multilateral environmental agreements, trade and investment rules, financing facilities and intellectual property rights regimes would all need to be aligned so as to facilitate the green technological transformation. Since many, although not all, existing new technologies are owned by the advanced countries and the cost of inducing green technological change will be much higher for developing countries relative to their incomes, there will be important distributional challenges connected with greening the global economy, which will also need to be addressed through the above-mentioned financing facilities and other new mechanisms of international cooperation.

This year's *World Economic and Social Survey* examines the means by which the technological revolution can meet the requirements and sustain the objectives of a green economy.

The complexity of technological change

The outcomes are uncertain

Technological change is a cumulative process, fraught with uncertainties as to direction and outcome. History also suggests that there is no simple technological sleight of hand for transforming production and consumption. Changes in the world's dominant technologies will lead to significant changes in social structure, market institutions, living arrangements and lifestyles.

Inevitably, radical technological change will have strong distributive effects across and within countries. Some countries and groups will be negatively affected by reduced demand for their products and resources. On the other hand, countries that keep up with research and development efforts and manage to generate new linkages with the rest of their economies will be better able to keep in step with the emerging technological trends and experience gains in wealth and welfare.

Technological change is closely linked to industrial upgrading and structural change

The biggest advances in technological capabilities and applications will have to occur in the developing world where technological upgrading involves structural changes in production. The capacity of an economy to generate new dynamic activities is key to sustainable development. Because production processes must change in order to sustain long-term growth and facilitate development, Governments must choose enabling policies. This may involve what the Austrian economist Joseph Schumpeter called "creative destruction": creating new economic activities to replace older, less productive ones. Selective investment, industry and technology policies will thus become essential for all countries pursuing sustainable development.

A Green National Innovation System (G-NIS) is needed to accelerate sustainable development

All countries have what has come to be called a national innovation system (NIS), which encompasses the educational system, scientific and technical research institutions, private firms' product development departments and other mechanisms through which products and production processes are redesigned. All countries have a national innovation system whether or not policymakers are conscious of its presence. A key responsibility of an effective NIS is building domestic capacity to choose, absorb and promote the technologies that are most conducive to enhancing dynamic sustainable development. This *Survey* proposes mainstreaming sustainable development objectives into existing national innovation systems and situating those objectives at their very core so as to create what it calls Green National Innovation

Systems (G-NIS). The G-NIS would also serve both to coordinate the reorientation of sector-specific innovation systems for agriculture, energy, construction, manufacturing and transport, among other sectors towards a focus on green technologies and to ensure consistency among green technology, industrial and demand-side policies.

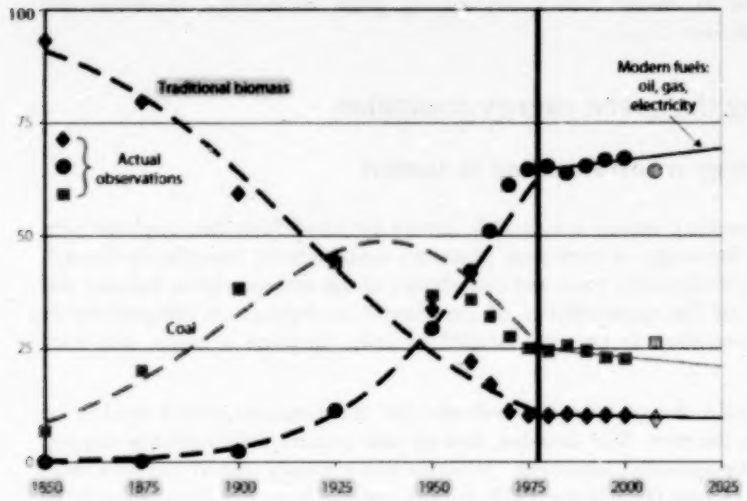
Accelerating the green energy transition

A radical energy transformation is needed

It is rapidly expanding energy use, mainly driven by fossil fuels that explains why humanity is on the verge of breaching planetary sustainability boundaries through global warming, biodiversity loss, and disturbance of the nitrogen-cycle balance and other measures of the sustainability of the Earth's ecosystem. A comprehensive global energy transition is urgently needed in order to avert a major planetary catastrophe.

While climate change scenarios indicate that the transition would need to be achieved within the next four decades, history and present developments suggest that this would be virtually impossible: previous major energy transitions took from 70 to 100 years (figure O.2). Since 1975, energy systems have stabilized around the use of fossil fuels with no visible shift in the direction of a new transition towards renewable and cleaner primary energy sources, despite national and international efforts to accelerate technological change in energy generation in response to the oil crises of the 1970s and increasing concerns about global warming. Progress has been made in achieving greater energy efficiency (as determined by use of energy per unit of output) and increased use of certain types of technologies with lower carbon content, but these achievements have been greatly outweighed by rising energy demand leading to continued increases in global greenhouse gas emissions. The high levels of economic growth that developing countries will need to achieve in the coming decades in order to meet their development targets will lead to further drastic increases in energy demand. Far more drastic improvements in energy efficiency and an accelerated shift to sustainable energy will thus be required if catastrophic damage through climate change is to be averted.

Figure O.2
Two grand-scale transitions undergone by global energy systems, 1850-2008
(Share of primary energy: percentage)



Sources: British Petroleum, "Statistical review of world energy 2010" (London, British Petroleum, 2010). Available from http://www.bp.com/productlanding.do?categoryId=6929&contentId=7044622; Arnulf Grübler, "Energy transitions", in "The Encyclopedia of Earth" (Washington, D.C., Environmental Information Coalition, National Council for Science and the Environment, 13 February 2011); and International Energy Agency, "Energy balances of non-OECD countries" (Paris, 2010). Available from http://www.iea.org/Textbase/nptoc/greenbal2010TOC.pdf.

Will such a transformation be feasible?

The long lifetimes of power plants, refineries, buildings and energy infrastructure make any energy transition necessarily a long-term affair. Global replacement costs of existing fossil fuel and nuclear power infrastructure are estimated at, at least, $15 trillion-$20 trillion (between one quarter and one third of global income). Some developing countries may be able to leapfrog directly to renewable energy sources, although the bulk of the energy infrastructure of most emerging and developing countries is already locked into the utilization of fossil fuels.

Many countries are already making efforts to foster a greener energy supply system, including through investments in energy innovation, feed-in tariffs and other price measures, and regulatory measures and efficiency standards designed to promote energy efficiency and diffusion of renewable and clean sources of energy. The *Survey* indicates, however, that the pace of progress of technological change is nowhere near that needed to reach the goal of full decarbonization of the global energy system by 2050. Clearly, existing efforts are just not generating a global solution; and increased efforts to accelerate change will therefore be needed in both developed and developing countries.

The task will be daunting, partly because of the massive investments locked into brown energy technology and its interdependencies with the broader economic system; and partly because, as present knowledge suggests, there may be technical

limits to the massive scaling up of renewable energy technologies (such as wind and solar power), given present conversion efficiency as well as the limits to deployment of those technologies and improvements in their energy-use efficiency.

Accelerating a green energy transformation is possible — but it will be difficult

There are examples of rapid national energy transitions. Portugal, for example, increased the share of renewables (including hydroelectric power) in total energy supply from 17 to 45 per cent in just five years, between 2005 and 2010. Such accelerated transitions will likely be easier in small and resource-rich or affluent economies than in large and resource-poor or low-income countries. The 1987 Montreal Protocol on reducing Substances that Deplete the Ozone Layer[1] is an example of a global instrument that has produced successfully a framework for inducing a worldwide radical and swift shift away from polluting technologies, with special support to developing countries for adopting new technologies.

The *Survey* concludes that accelerating the green transition will require ensuring coherence across a broad range of policies among all countries. These policies will, by and large, have to be adapted to local conditions and opportunities, and implemented at the national level. However, these national policies will need to "add up", which is not now the case, so as to meet global targets, especially those for reducing greenhouse gas emissions, given the global nature of climate change.

Global targets need to recognize difference in levels of development

A global energy transformation should simultaneously meet emission targets and facilitate an upward convergence of energy usages of developing and developed countries (the per capita income and energy availabilities of the former are on average one tenth those of the latter). The Kyoto Protocol[2] to the United Nations Framework Convention on Climate Change[3] requires signatories to reduce their yearly emissions to about 13 tons of CO_2 emissions per person by 2012, which seems achievable. This target would be coupled with declining rates of emissions increase in developing countries. To stay within the absolute CO_2 concentration limit of 450 parts per million accepted by the Copenhagen Climate Change Summit, accelerated progress towards a renewable or green energy transformation will be needed, as this limit would entail cutting annual emissions gradually to 3 tons per person by 2050, or less for any more stringent limit set to stabilize the climate.

However, given that current knowledge suggests that there may be limits to the degree to which renewable technologies can be scaled up and the extent to which energy efficiency can be increased to meet growing energy demand, caps on energy consumption (with significant implications for production and consumption processes) to complement emission reduction targets may need to be considered. The *Survey* estimates that the emissions cap would be equivalent to primary energy consumption of 70 billion joules per capita per year, which means that the average

[1] United Nations, *Treaty Series*, vol. 1552, No. 26369.
[2] Ibid., vol. 2303, No. 30822.
[3] Ibid., vol. 1771, No. 30822.

European would have to cut his or her present energy consumption by about half and the average resident of the United States of America by about three quarters. Most developing-country citizens would still be able to significantly increase their average energy usage for some period of time. Even so, developing countries will not be able to avoid making the green energy transformation as well to ensure that global emission reduction targets can be met.

Green energy policies need to be coherent along production and consumption chains

In accelerating technological transformation to meet emissions and energy-use targets, the *Survey* recommends that policies and actions be guided by four key goals.

(a) Improving energy efficiency in end use without expanding consumption where energy-use levels are already high

Reducing energy use through technological change — entailing production of factory equipment, home appliances, and automobiles that are more energy-efficient — is potentially as important as installing clean energy supply facilities. This will, however, require a quantum increase in support for research and deployment in a relatively neglected area. In order for macrolevel gains to be reaped from end-use efficiencies, it is important that improved energy efficiency not be allowed to become the basis for an increase in activity and consumption in developed countries and that such increases be permitted only in countries that are still overcoming energy and income deficits.

(b) Supporting a broad energy technology development portfolio globally while adapting more mature technologies in specific locations

A wide range of technologies exist for producing clean energy and reducing energy intensity of production and consumption. Most experts concur that Governments, in particular advanced economies, should promote the development of a broad portfolio of technologies (including renewables such as solar, wind, geothermal and hydropower) along the full chain of technology development (research, development and demonstration, market formation, diffusion and commercial adaptation). Most developing countries may opt for a more focused portfolio, given that their entry into energy technological transformation would take place at maturer stages of the process.

(c) Supporting more extensive experimentation and discovery periods

Support for technological development must also allow for experimentation sufficient to ensure that the more efficient technologies are scaled up, with the end goal being, in all cases, commercial viability. Government support programmes should ensure that consistent improvement of technologies is focused towards widespread usability beyond the demonstration stage and should avoid a premature locking in of suboptimal technologies that are not viable in non-specialized situations.

(d) Using "smart" governance and accountability strategies in energy-related technological development

It is important, at the global and national levels, to expand oversight by independent and broadly representative technical bodies of the allocation of public funds for technological development. Support programmes should have sufficient flexibility to provide and withdraw resources based on potential and opportunity cost considerations. Governments can subsidize and reward efforts by private companies to achieve progressively higher energy efficiencies in end-use products such as factory equipment, cars and home appliances. An excellent example of such an approach is Japan's Top Runner programme, which turns the most efficient product into a standard to be met by other manufacturers within a given time period. Upgrading towards technologies that are low on emissions and highly energy-efficient should be a key objective of industrial policy.

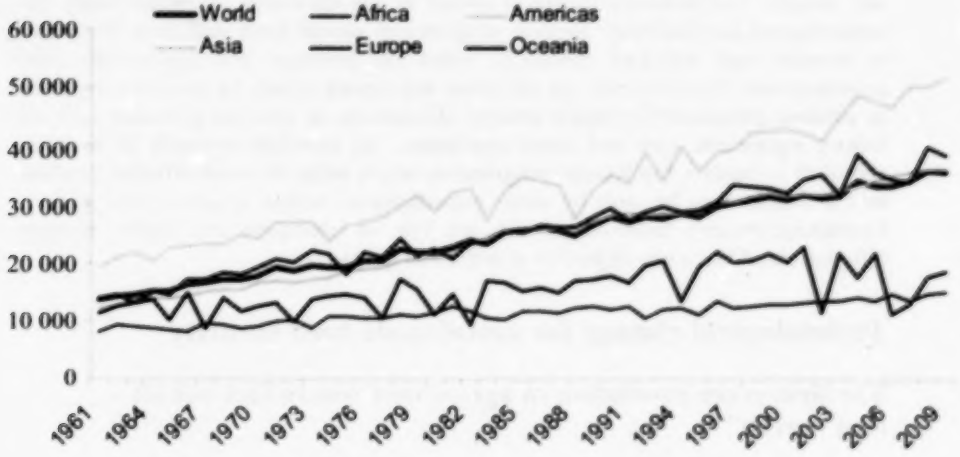
Technological change for sustainable food security

The first green revolution in agriculture was in fact not all that "green"

The recent food crises laid bare deeper structural problems within the global food system and the need to increase investment and foster innovation in agriculture so as to accelerate growth of food production in order to overcome hunger and feed a growing world population. Achieving this goal with existing agricultural technologies and production systems would entail further increases in greenhouse gas emissions, water pollution, deforestation and land degradation, which in turn would impose further environmental limits on food production growth itself.

In large parts of the world, food systems were shaped to a considerable extent by the so-called green revolution of the 1960s and 1970s, which pushed agricultural yields as much through much more intensive use of irrigation water and environmentally harmful chemical fertilizers and pesticides, as through the introduction of new seeds varieties (figure O.3).

Figure O.3
Diverging productivity growth of cereal food crops, by region, 1961-2009
(Hectograms per hectare of cultivated land)



Source: Agricultural Science and Technology Indicators (ASTI), facilitated by the International Food Policy Research Institute (IFPRI). Available from http://www.asti.cgiar.org/data/.

A truly green agricultural revolution is now needed ...

Food security must now be attained through green technology so as to reduce the use of chemical inputs (fertilizers and pesticides) and to make more efficient use of energy, water and natural resources, as well as through significant improvement of storage facilities, and marketing to reduce waste. An extensive menu of already available green technologies and sustainable practices in agriculture (which have been successfully adopted with large productivity gains in developing-country contexts) can be deployed to lead the radical transformation towards sustainable food security, including technologies and practices such as low-tillage farming, crop rotation and interplanting, water harvesting and recycling, water-efficient cropping, agroforestry and integrated pest management. Further, biotechnology, genetic engineering, food irradiation, hydroponics and anaerobic digestion hold out the promise of improving the resistance of food crops to pests and extreme weather, increasing their nutritional value and reducing food contamination and greenhouse gas emissions. Development of new high-yielding varieties of crops, a central focus of the first green revolution in agriculture, should continue, provided such development is combined with improved water management and better use of agrochemical and organic inputs so as to substantially reduce their adverse ecological impacts, as in the System of Rice Intensification (SRI) which raises crop yield while reducing water, chemical fertilizer and pesticide usage through simple changes in the times when and the means by which rice seeds are transplanted and irrigated.

... a revolution with a key focus on small-scale farming

While these technologies need to be improved further, the main challenge is to change incentive structures so as to encourage their widespread use. The *Survey* reaffirms the view taken by the international community at the 1996 World Food Summit and when defining responses to the food crisis of 2007-2008, namely, that the main policy focus on the supply side should be promotion and development of sustainable agriculture, as practised by small farm holders in developing countries, since it is in this area that most gains in terms of both productivity increases and rural poverty reduction can be achieved. In respect of the cultivation of most food crops, the optimal farm size is small.

The green revolution of the 1960s and 1970s bypassed many small farm holders in developing countries because of its focus on a single technological package — one that did not address the context-specific conditions of millions of farmers, mainly in Africa. Without providing adequate technologies and a larger range of supportive services (rural infrastructure, like rural roads and sustainable irrigation systems, education and training and access to land, credits, affordable inputs and market information), small farm holders are, typically, not able to take advantage of available technological improvements.

A comprehensive approach to food security is essential ...

The policy challenge is thus twofold. First, effective ways must be found to adapt sustainable agricultural technologies to local conditions and the needs of small holders. Second, dynamic innovative processes must be introduced at the local level, including by putting in place the necessary support infrastructure and services.

The *Survey* argues that a comprehensive policy approach is needed to take on these challenges, which would involve both a comprehensive national framework for sustainable use of resources, and new technology and innovation with the capacity to increase the productivity, profitability, stability, resilience and climate change mitigation potential of rural production systems. Water conservation, soil protection and biodiversity enhancement need to form part of an integrated approach aimed at sustainable management of land and other natural resources, which should both be sensitive to the issue of trade-offs and build on synergies between the forest and agriculture sectors. In the context of competitive land uses, many solutions involving difficult choices will be reachable only through open and inclusive negotiation and discussion. Nevertheless, the aforementioned synergies between sectors (resulting, inter alia, in reduced deforestation and increased land productivity, and sustainable water supply) present important "win-win" options through better resource management facilitated by an enabling institutional environment.

... and will need to be supported by an enabling institutional environment

Countries should consider placing a Sustainable Agricultural Innovation System (SAIS) at the centre of a comprehensive policy approach to achieving food security and environmental sustainability. The Sustainable Agricultural Innovation System,

as the agricultural and natural resource management pillar of a Green National Innovation System, would link the multiplicity of actors that participate in national innovation systems in agriculture: universities, research institutions, firms, farmers, civil society organizations and private foundations.

Sustainable transformation of agriculture requires greater national capacities to adapt to continuous environmental and market change. A dynamic Sustainable Agricultural Innovation System would provide the framework for the policy coherence needed to accelerate the desired transformation of agriculture, including by laying out the strategies for easing the adaptation of green technologies and sustainable crop practices, and for improving the capacity of small-scale farmers to innovate through learning and experimentation and to secure better access to input and product markets through partnerships with other actors (research institutions, private corporations, non-governmental organizations, and local governments).

Research capacities will need to be rebuilt

The creation of a Sustainable Agricultural Innovation System able to assume a leadership role in the new green revolution will require a new effort to rebuild global and national research capacities in agriculture and natural resource management, including through increased financial support for agricultural research and development. Experience from the previous green revolution has shown that the adoption of new technology for food security requires long-term financial support for research and development. A significant component of that support had been channelled through the Consultative Group on International Agricultural Research (CGIAR) network, which lost much of its capacity to exercise leadership in further technological innovation when the flow of resources became unstable and decreased. The international and national public sectors have an important role to play in facilitating farmers' free access to information and technology by providing adequate incentives to the private and not-for-profit sectors to collaborate in producing public goods, and by reinvigorating and helping to reorient the focus of networks like CGIAR as part of a Sustainable Agricultural Innovation System and international cooperation.

The previous green revolution took less than a decade to increase food production at impressive rates. The new revolution in agriculture needed to improve food security and halt the depletion of natural resources can, with adequate financial resources and political support, be produced through the incorporation of available technology in small-scale farming.

International support will be critical

The international community has much to contribute to the transformation in agriculture by removing obstacles to the transfer of technology (including privately held patents); delivering on its commitment to mobilize $20 billion in additional official development assistance (ODA) for sustainable agriculture, as pledged at the 2009 G-8 Summit held in L'Aquila, Italy; providing small-scale farmers with expanded access to mechanisms for the payment of environmental services; and, in the case of Organization for Economic Cooperation and Development (OECD) member countries, eliminating agricultural subsidies.

Eliminating disproportions in the degree of harm inflicted by natural events

The frequency of climate-related disasters is increasing

The frequency of natural disasters has quintupled over the past 40 years. By far, most of this increase can be accounted for by the greater incidence of hydro-meteorological disasters (floods, storms, droughts and extreme temperatures) associated with climate change. Major disruptions in the ecosystem, often referred to as "extreme events", have become more likely. Such events could already be occurring in the area of biodiversity (resulting in rapid extinction of species) and may be close to occurring in the fisheries domain and in some water systems.

Developing countries tend to suffer more from the adverse consequences of natural hazards through multiple vulnerabilities associated with lower levels of development and inadequate resources, which constrain their efforts to build more adequate and resilient infrastructure and implement adequate disaster risk management strategies.

Disaster risk management should be an integral part of national development strategies

Despite the urgent threat involved, disaster risk management and adaptation to climate change in developed and developing countries alike have not been mainstreamed into broader decision-making processes. In practice, responses are most often largely event-driven. The *Survey* emphasizes, in contrast, that investment and technology decisions related to disaster risk reduction and adaptation to climate change should be embedded in national development strategies. This approach is in line with that set out in the Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters[4] for disaster risk management and in the Cancun Adaptation Framework (2010).[5]

Existing technologies can be deployed

Reducing disaster risk in a sustainable manner will involve changes in the design of settlements and infrastructure, including roads, rail systems and power plants. Existing modern technologies, including sea walls, tidal and saltwater intrusion barriers, and improved water and crop storage, appear by and large to be adequate to the task of providing protection against most (non-extreme) hazards. Further technological innovation, which draws on indigenous knowledge, is needed to adapt disaster-resilient infrastructure, housing and natural coastal protection to local conditions and to make the technologies more affordable for developing countries.

[4] A/CONF.206/6 and Corr.1, chap. I, resolution 2.

[5] FCCC/CP/2010/7/Add.1, decision 1/CP.16, sect. II.

National efforts need to be supported through regional and global cooperation

Natural hazards know no national borders and often affect larger regions. National-level disaster risk management will thus need to be linked to regional mechanisms of cooperation, including for maintaining joint monitoring, forecasting, and early warning systems, and defining risk reduction strategies.

International cooperation will also require facilitating technology transfer to developing countries in order to reduce the local harm caused by global warming. Technology transfer should ensure that recipients have the capacity to install, operate, maintain and repair imported technologies. It will be important for local adapters to be able to produce lower-cost versions of imported technologies and adapt imported technologies to domestic markets and circumstances. In the Hyogo Framework for Action and the United Nations Framework Convention on Climate Change, the international community identified the need for external financial support for local adaptation and disaster resilience efforts, including through the mobilization of resources for dedicated multilateral funding.

Technology transfer and international cooperation

Multilateral trading rules and international finance need to be "greened"

A sustained scaling up and reform in international cooperation and finance are required to achieve the global technological revolution. Scaling up and reforms require action in three areas. First, an international regime for green technology-sharing will have to be established to facilitate technology transfers to and development in developing countries. This will include using a broader set of tools in intellectual property and multilateral trade policies. Second, securing adequate development finance and policy space to energize developing-country efforts to upgrade production technologies towards environmental sustainability is indispensable. Third, international governance and cooperation have to be upgraded.

An effective global technology development and diffusion regime needs to be established

Expanding action in nurturing and upgrading green production and consumption technologies in developing countries must be a key goal of international cooperation. However, publicly guided international mechanisms of technological diffusion have limited precedents, since, historically, the bulk of technological knowledge has been embodied and transferred as private property through the operations of private companies. The successful experience of CGIAR is an example of how rapid worldwide diffusion of new agricultural technologies can be effected through a publicly supported global and regional network of research institutions. In the climate change area, building international public policymaking capability can draw upon the experiences of already existing international scientific networks and the example of multi-stakeholder cooperation provided by the work of the Intergovernmental Panel on Climate Change. The international community took

the first step towards meeting this challenge in reaching an agreement at the Conference of the Parties to the United Nations Framework Convention on Climate Change at its sixteenth session, held in Cancun, Mexico, from 29 November to 10 December 2010, to set up a Technology Executive Committee (TEC) as a policymaking body[6] to implement the framework for meaningful and effective actions to enhance the implementation commitments on technology transfer.[7] At the same session, agreement was reached on establishing an operational body to facilitate a networking among national, regional, sectoral and international technology bodies, to be called the Climate Technology Centre and Network (CTCN).[8]

The intellectual property rights regime needs to be changed

Managing global intellectual property rights is also crucial, as patenting is highly aggressive in various areas of green technology. For example, a small group of private companies is actively patenting plant genes with a view to owning the rights to the genes' possible "climate readiness" in the future. Granting intellectual property rights constitutes and should always remain a public policy action, one whose intention is to consistently stimulate — not restrict — private initiative in technological development. At the present time, the granting of a patent is the most widespread and lucrative technological development incentive.

Obtaining agreement among countries on the public policies needed to accelerate invention and diffusion is critical. Currently, protecting private intellectual property rights by enforcing exclusive use and deployment by its owner is the main approach. Internationally, spurring green technological development will require a wider mix of public sector strategies, which guarantee a commercial incentive substantial enough to enable private parties to use subsidies and public purchases of technology at reasonable cost in their research undertakings, while constraining monopolistic practices which restrict diffusion and further development.

Public policy tools could include global funding for research, to be placed in the public domain for widespread dissemination, under the same modality utilized in the green revolution in food agriculture in the 1960s and 1970s. With technology funds, it should be possible to establish international innovation networks within different areas of technology. The overall strategy could also include global awards for the formulation of technical solutions to well-defined problems, and public purchase at appropriate prices of private technology for deployment in the public domain. The private sector must continue to play a vital role in technological development, particularly in developing and adapting basic inventions for actual application.

The new international regime should allow special and differential access to new technology based on level of development. For example, developing-country Governments and firms could be allowed to adapt technology but begin paying royalties only when its use has begun to yield commercial returns. Where exclusive private-sector rights of use to vital technology are a hindrance to the development of other needed technology or to widespread use, the technology regime must have a mechanism (such as exists in certain areas of public health) for granting a "compulsory licence" that places said technology in the public domain.

[6] Ibid., decision 1/CP.16, para. 117 (a).
[7] Ibid., para. 119.
[8] Ibid., paras. 117 (b) and 123.

Multilateral trading rules should grant greater flexibility to developing countries in their conduct of industrial policies

Present project-oriented loan conditionality and the proliferation of international financing mechanisms thwart developing countries' efforts to design and implement coherent strategies for sustainable development. Investment measure-related restrictions (from the multilateral trade regime and bilateral treaties) shackle attempts to implement industrial policy at a time when developed-country industrial interventions for building green technologies are proliferating. Thus, it is important to guarantee developing countries sufficient policy space for industrial development.

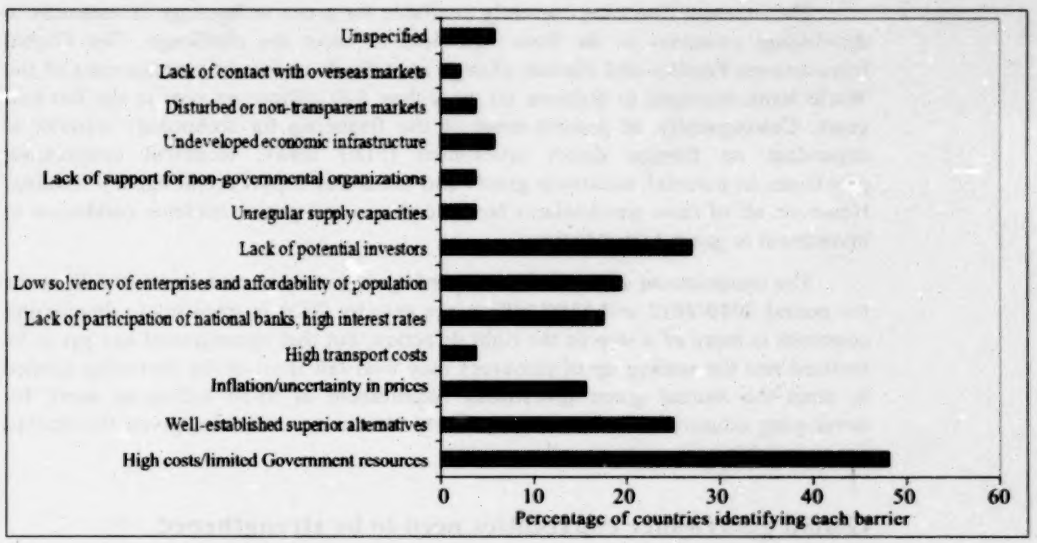
The multilateral trading system should allow developing countries higher levels of bound tariffs and a greater range in those levels than were proposed under the Doha process. It is also important to consider recognizing industrial policies encompassing, for example, domestic content and technology transfer requirements so as to enable developing countries to undertake sector-specific programmes aimed at building dynamic local industries.

Environmental standards have served as effective industrial policy instruments for accelerating technological transformations. At present, technical standards are often determined by Governments (unilaterally or through agreements among a reduced number of countries) or set by private companies. Wider participation of all parties in the setting of these standards, especially developing countries, should guarantee that the introduction of environmental standards (including through green labels and ecological footprint certificates) will not become a means of practising unfair trade protectionism. The Montreal Protocol process through which the substances to be banned and the pace of their elimination were identified may serve as an example in this regard.

Financing of green technology transfers will require domestic and international financial reforms

To facilitate the introduction of the new green technologies, investment rates in developing countries will have to be stepped up considerably. Inadequate financing has been consistently identified by developing countries as the greatest obstacle to their rapid adoption of clean technologies (figure O.4).

Figure O.4
Economic and market barriers to technology transfers reported in technology needs assessments
(Proportion of countries identifying any given barrier)



Source: United Nations Framework Convention on Climate Change, Subsidiary Body for Scientific and Technological Advice "Recommendations on future financing options for enhancing the development, deployment, diffusion and transfer of technologies under the Convention: report by the Chair of the Expert Group on Technology Transfer" (FCCC/SB/2009/2), figure 6.

The financing challenge is enormous. In line with other studies, a recent report on the green economy released by the United Nations Environment Programme estimates that about 2 per cent of world gross product (WGP) (approximately $1.3 trillion) would need to be spent on green investments every year over the coming decades. Given the limited time frame for achieving the required technological transformation, the required global level of green investments would need to be reached within the next few years.

At least one half of the required investments would have to be realized in developing countries. Enhanced domestic resource mobilization (private savings and public revenues) should be key to financing the additional investment effort over the medium run. Many developing countries have poorly developed markets for long-term financing and weak fiscal basis, which limit the scope for substantial increases in domestic funding for long-term investment in the near term. Other constraints on investing domestic resources in developing countries originate from deficiencies in the global financial and payments system. A number of developing countries hold a significant portion of domestic savings as international reserves, which in large measure have been invested in financial assets in developed countries. The volatility of global capital and commodity markets are an important determinant underlying this form of self-insurance and substantial net transfer of financial resources to advanced market economies. Reforms of the international payments and reserve system that would stem global market volatility and reduce the need for reserve

accumulation by individual developing countries could liberate substantial resources (including from sovereign wealth funds through the use of special drawing rights) for long-term financing in green investments. Moreover, this would facilitate effective net resource transfers to developing countries.

The external financing currently available for green technology investments in developing countries is far from sufficient to meet the challenge. The Global Environment Facility and climate change trust funds under the management of the World Bank managed to disburse no more than $20 billion per year in the last two years. Consequently, at present most of the financing for technology transfer is dependent on foreign direct investment (FDI) flows, technical cooperation provisions in external assistance grants and loans and export credit agency funding. However, all of these mechanisms lack incentives and policy contexts conducive to investment in green technologies.

The commitment set out in the Copenhagen Accord to mobilize $30 billion for the period 2010-2012 and $100 billion per year by 2020 in transfers to developing countries is more of a step in the right direction, but that commitment has yet to be realized and the scaling up of resources may well fall short of the financing needed to meet the annual green investment requirement of $650 billion or more for developing countries. The scaling up likely also comes too late, given the limited time available.

Global governance capabilities need to be strengthened

The proposed reshaping of national development efforts and strengthened international commitment in the areas of technological development and cooperation, external assistance, investment finance and trade rules will require stronger mechanisms of global governance and coordination. Within the next three to four decades, all of these efforts must "add up" to achieving what today seems to be a set of almost unattainable targets, including a reduction in per capita carbon emissions by almost three fourths and the eradication of poverty, which will require an almost 10 times greater availability of modern energy sources by those now counted as poor.

The *Survey* recognizes that the bulk of the efforts to carry out a technological transformation must occur at the country level and build upon local conditions and resources. The need for an effective global technology policymaking body has already been indicated. If the overall global objectives are to be achieved, two critical conditions need to be fulfilled. First, more effective monitoring and verification of performance on international commitments are needed. As regards establishing the corresponding mechanisms of common accountability, lessons can be drawn from existing modalities in other areas, such as the trade policy review process of the World Trade Organization.

Second, much greater coherence will be required among the now noticeably disjointed multilateral architectures for environment, technology transfer, trade, aid and finance so as to facilitate coordination among what will likely be a diverse set of country strategies for green growth and ensure that they add up to global targets for environmental sustainability.

At the United Nations Conference on Environment and Development, held in Rio de Janeiro from 3 to 14 June 1992, the community of nations reached agreement on a "precautionary principle" to serve as a guide to public policy. According to that principle, in the absence of scientific consensus that a particular action or policy is harmful to the public or to the environment, the burden of proof that the suspect action or policy is *not* harmful rests with the party or parties implementing it. The precautionary principle determines that there exists a social responsibility to protect the public from exposure to harm in cases where scientific investigation has found a plausible risk of harm, which implies that all possible means should be applied towards achieving sustainable development.